# Application of risk analysis and dealing with uncertainties

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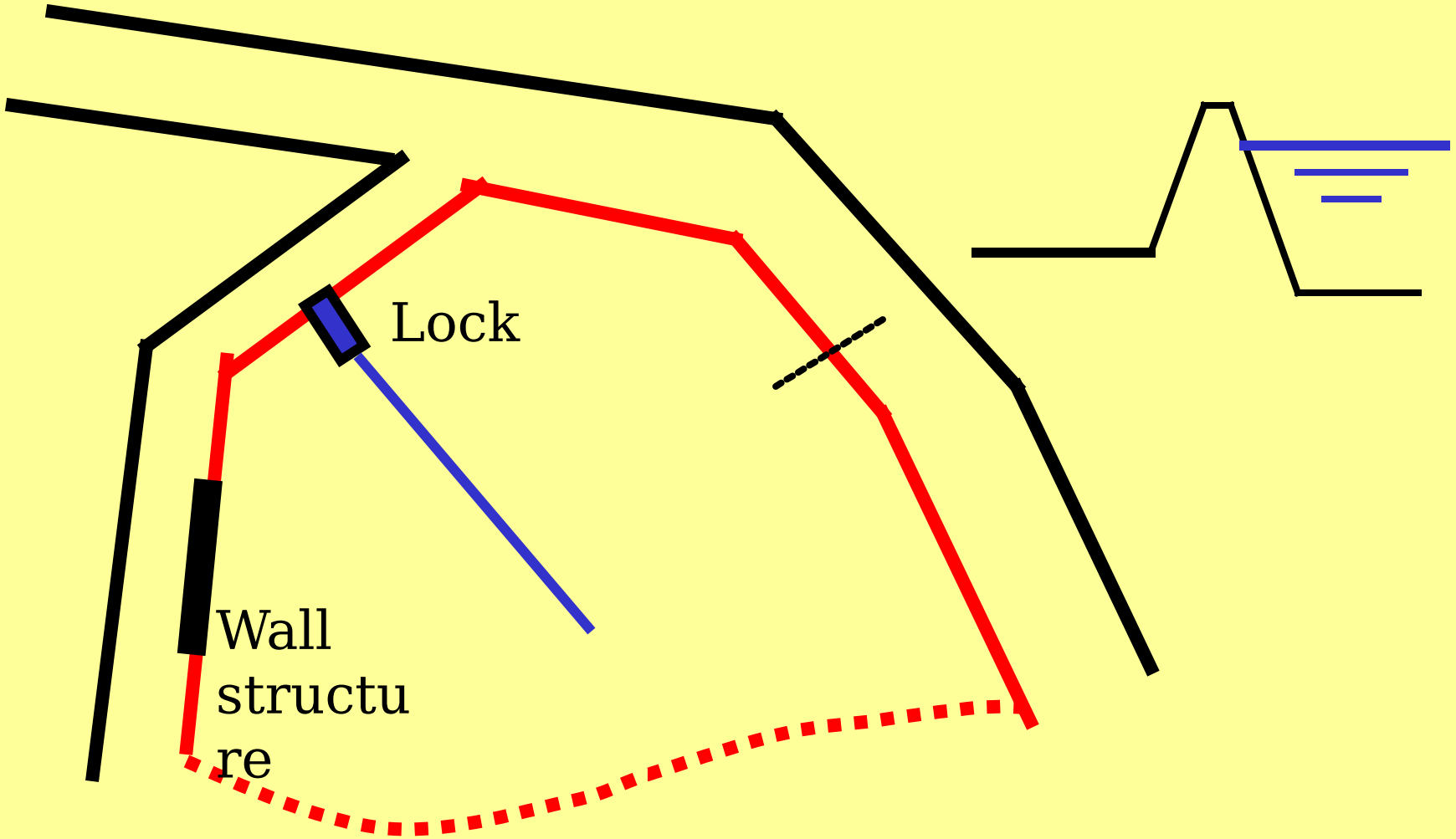
# Risk based decision making

1. definition of the system
2. inventory of hazards and mechanisms
3. physical and statistical modelling
4. failure probability calculations
5. consequences modelling
6. risk analysis calculations
7. assessment, management and communication
8. decisions

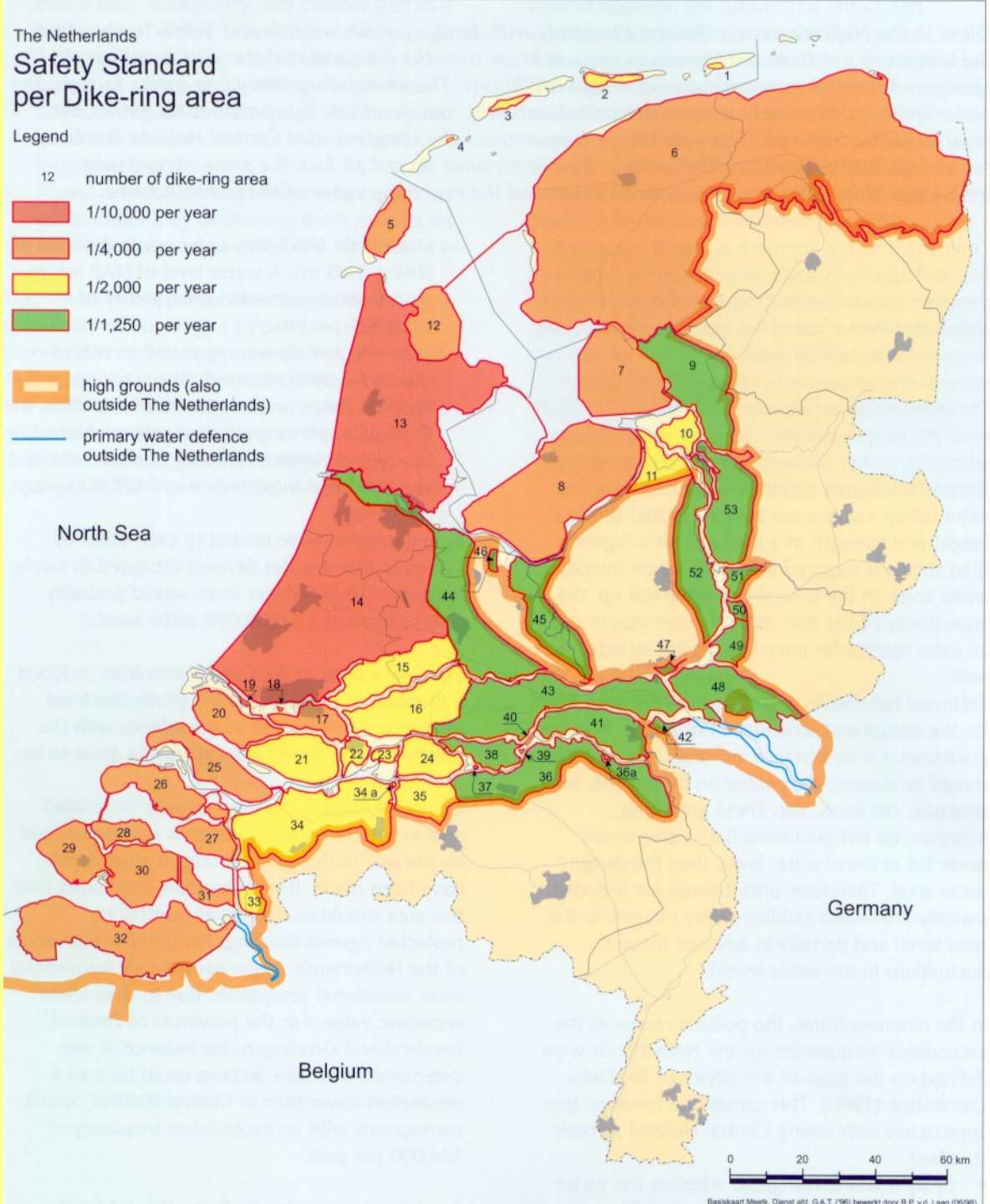
# Design and assessment principles for the Dutch flood defence systems

- **risk based principles since 1956**
- **return periods in The Water Act**
- **present elaboration rather primitive**
- **development into more advanced methods**




# STEP 1 Dike ring system

- **Dike rings**


The Netherlands
Safety Standard
per Dike-ring area
Legend
12 number of dike-ring area
1/10,000 per year
1/4,000 per year
1/2,000 per year
1/1,250 per year
high grounds (also outside The Netherlands)
primary water defence outside The Netherlands
North Sea
Germany
Belgium
0 20 40 60 km

# STEP 2 Qualitative risk analysis

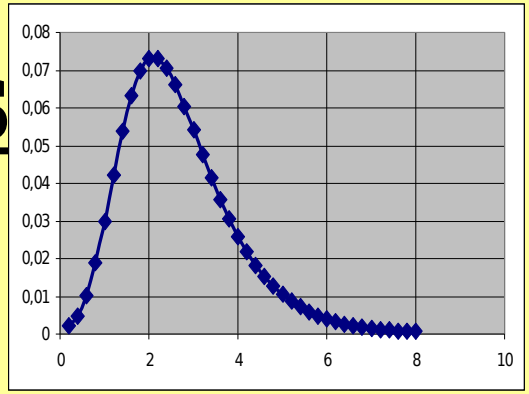
**Hazards / loads**

**water levels**
**river discharges**
**wind speeds**
**ship collision**

**Mechanisms**

**overtopping**
**geotechnical instability**
**revetment failure**
**piping**
**failure of steel and concrete elements**

# STEP 3 Models



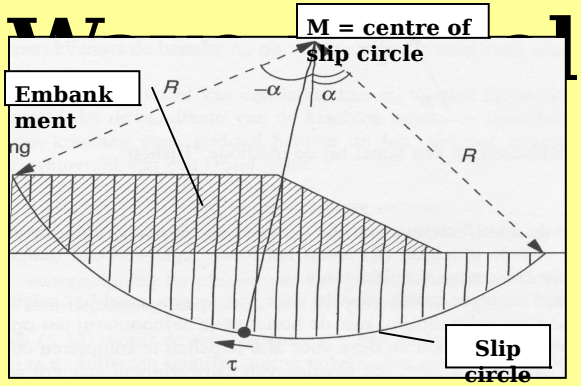

**Physical**

**Bisshop**

**Bretschneider**

**River models**

**W… …ls**




**Statistical**

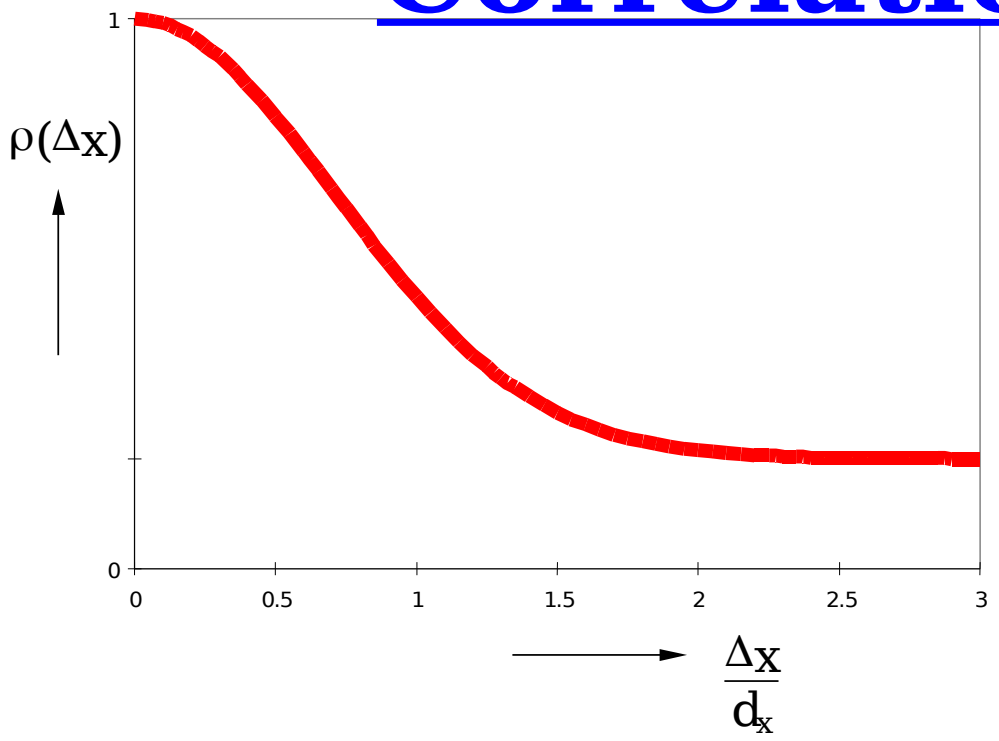
**Distribution type**

**Mean**

**Standard deviation**

**Correlation in space**

# Spatial Correlation



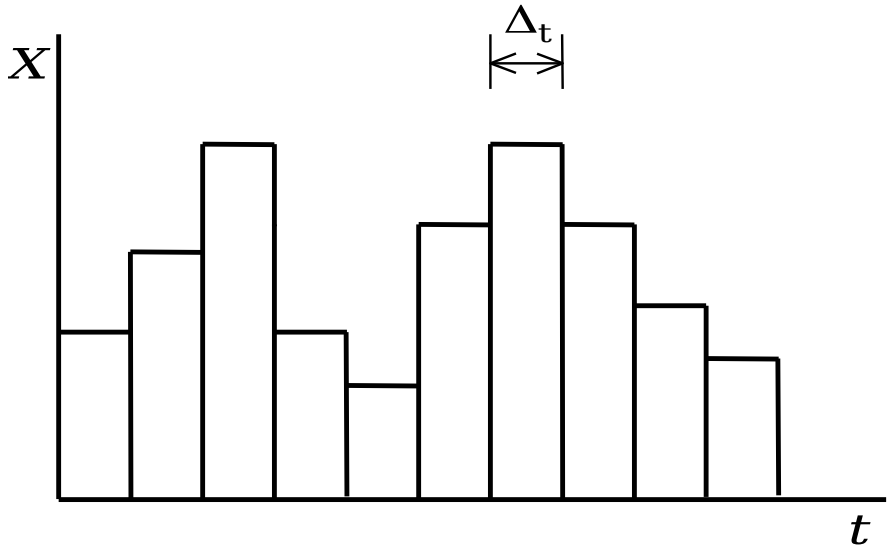

$$\rho(\Delta x) = \rho_x + (1 - \rho_x)\exp\left(-\frac{\Delta x^2}{d_x^2}\right)$$

**Example:**

Angle of friction $\phi$:

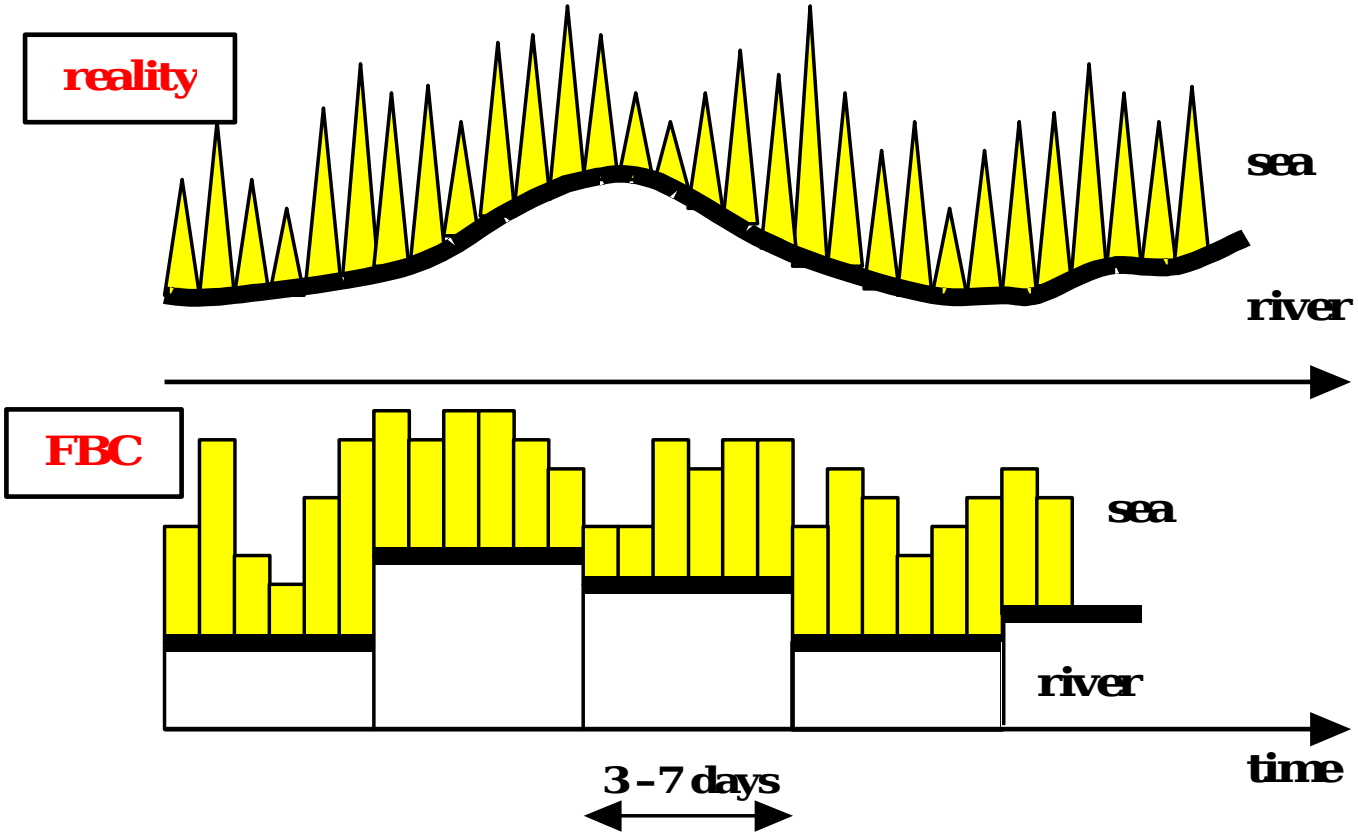
- lognormal
- $\forall \mu = 30^o$
- $\forall \sigma = 3^o$
- $\forall \rho_x = 0.2$
- $d_x = 50$ m

# Modeling time variability




**FBC model, parameter $\Delta_t$**

# Water level at arbitrary location



# Overview of the random variables

| load elements | geometry | materials |
|---|---|---|
| sea levels | dike height | surface roughness |
| wind velocities | toe height | cohesion |
| wind direction | slopes | angle of friction |
| discharges | bottom height | soil density |
| lake water levels | dune height | grain size |
| inner water levels | layer thicknesses | piping resistance |
| storm duration | piping lenght | |
| prediction errors | | |

| materials |
|---|
| grass properties |
| revetment density |
| revetment dimensions |
| revetment resistance |
| erosion parameters |
| storage volume |
| closure operation |

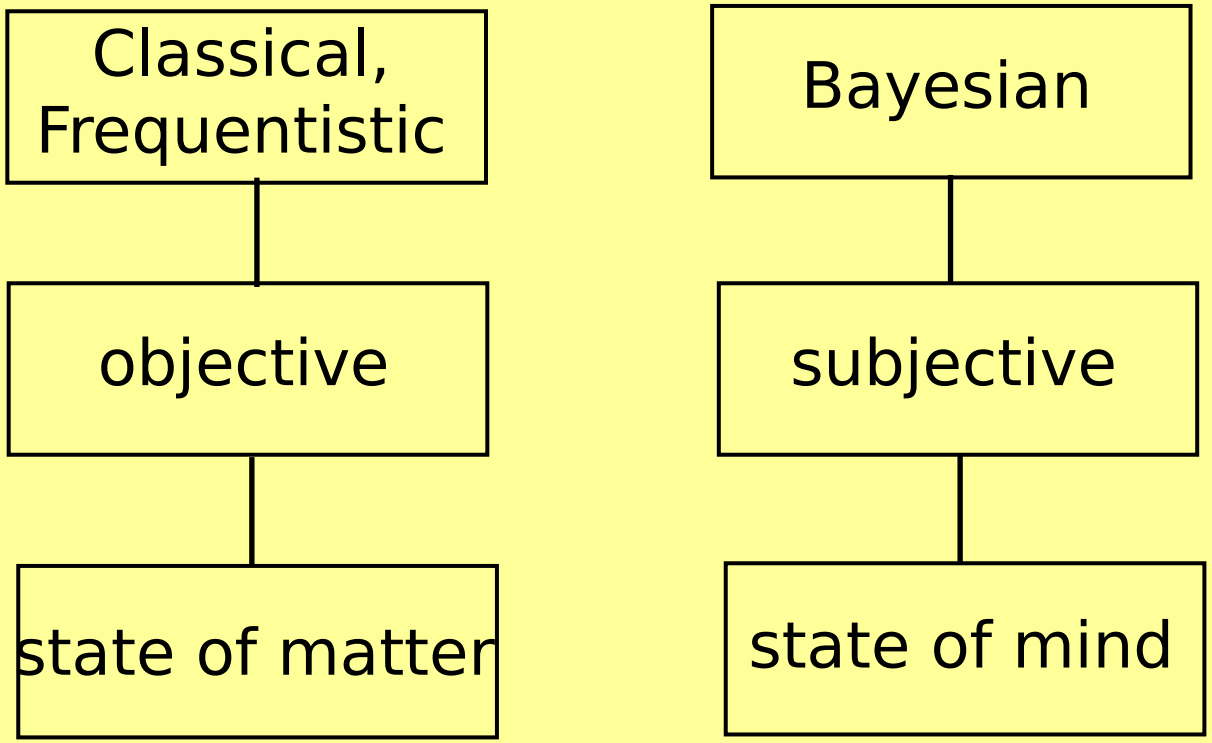
model uncertainties
statistical uncertainties

# Do we have sufficient data..? Should we stop here..?

- **Or follow the Bayesian approach:**

- **Include statistical and model uncertainty**
- **Partly subjective estimates**
- **There is no better way**
- **Logic and consistent decision making**
- **Correct in the limit of full information**
- **Correct on the average**

# Two probability notions



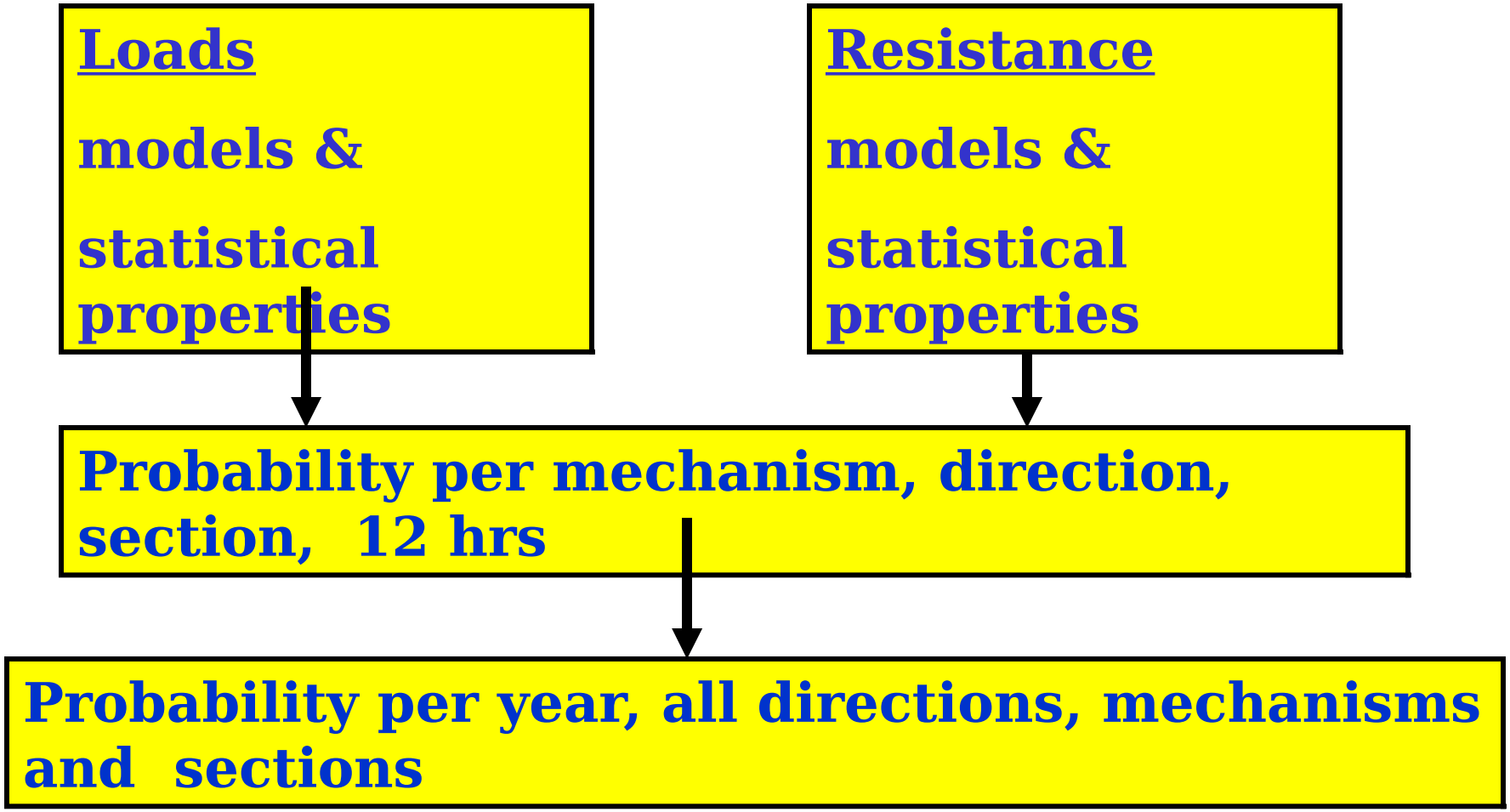
# Car example

- **brakes: 50% type A en 50% type B**
- **type A  okay / type B  not reliable**
- **all cars should be checked**
- **carefully you drive to the garage**
- **they find out you have type A**
- **you are happy again and drive normally**
- **The car remained unchangede !!**

# Savage:

- **Three experiments**
  - **Tea drinking lady**
  - **Music expert**
  - **A bit tipsy guy on a party**

# Step 4 Reliability Calculation (PC-Ring)



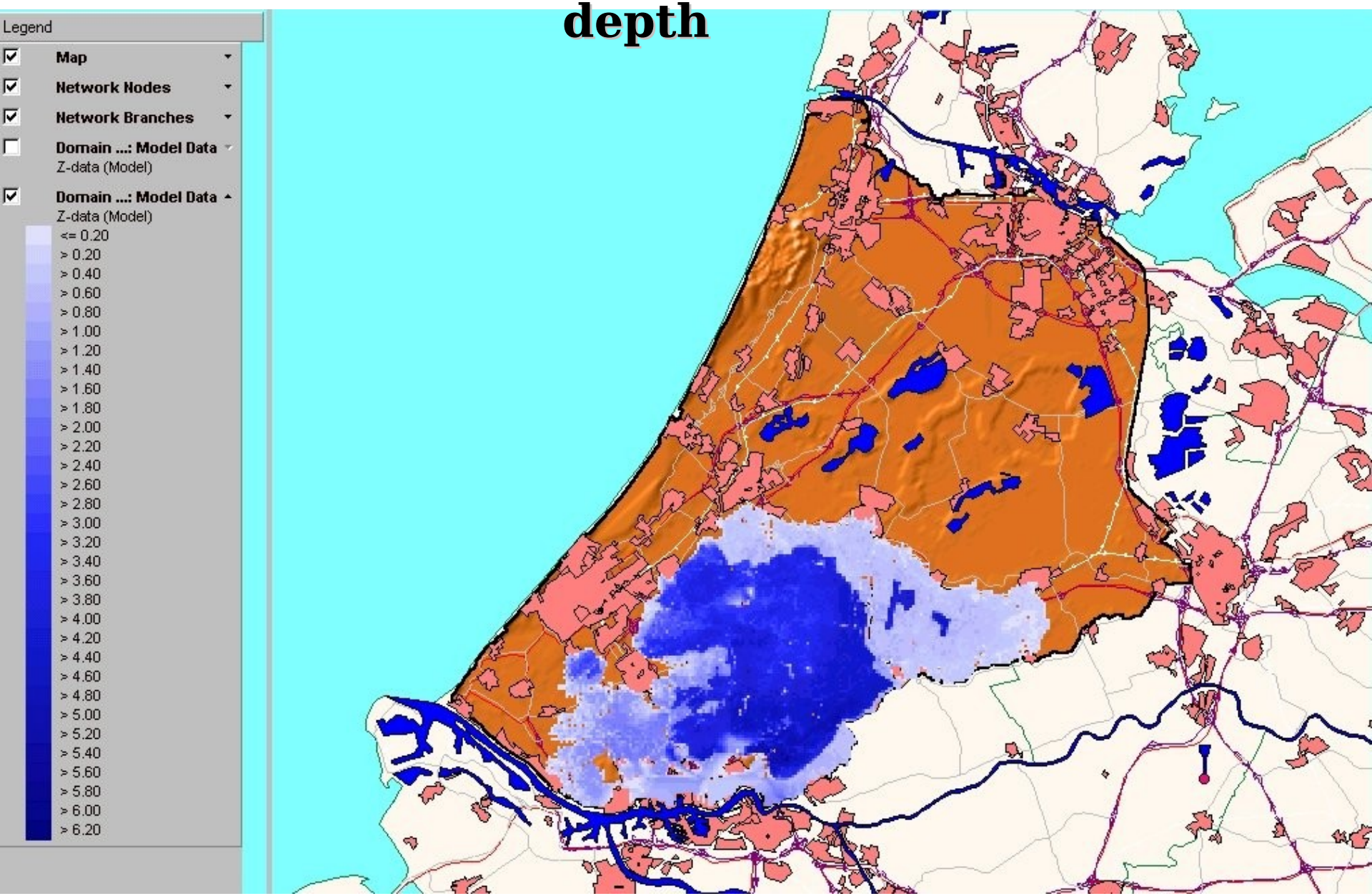
# Step 5 Consequences analysis

- Depth h(t)
- Velocity v(t)
- Wave height $H_s$
- Duration

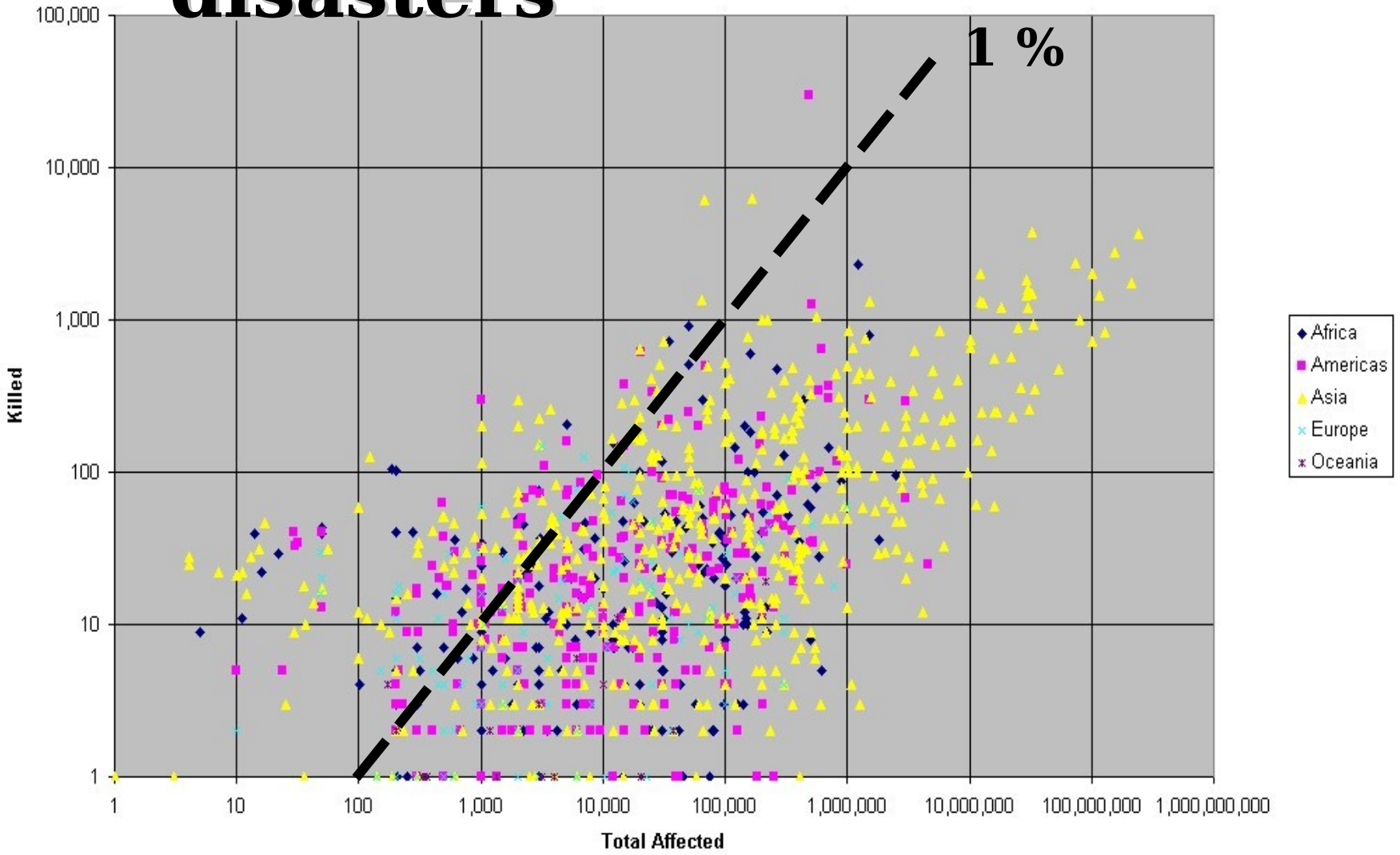
- types of land use
- number of people
- infrastructure
- toxic materials

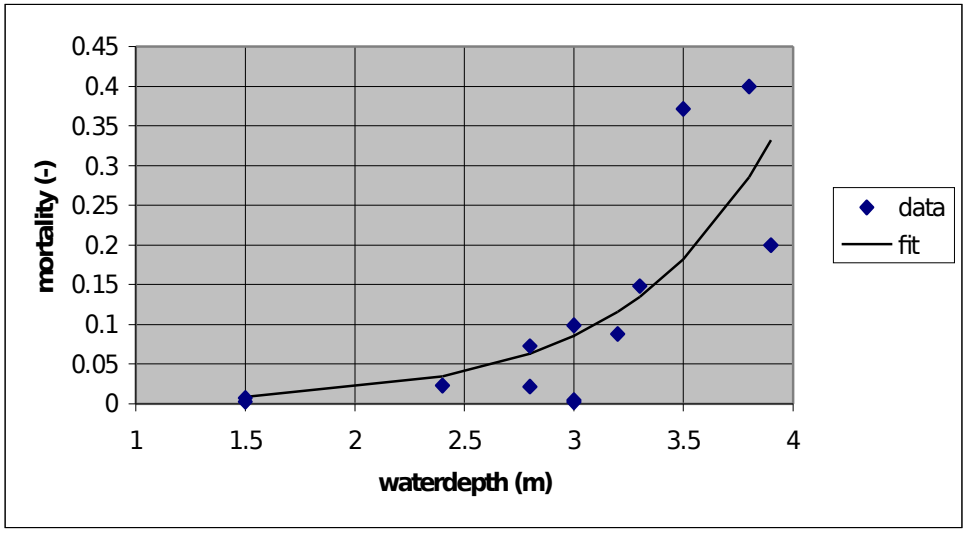
- Casualties
- Economical damage
- Environmental damage

# Water depth

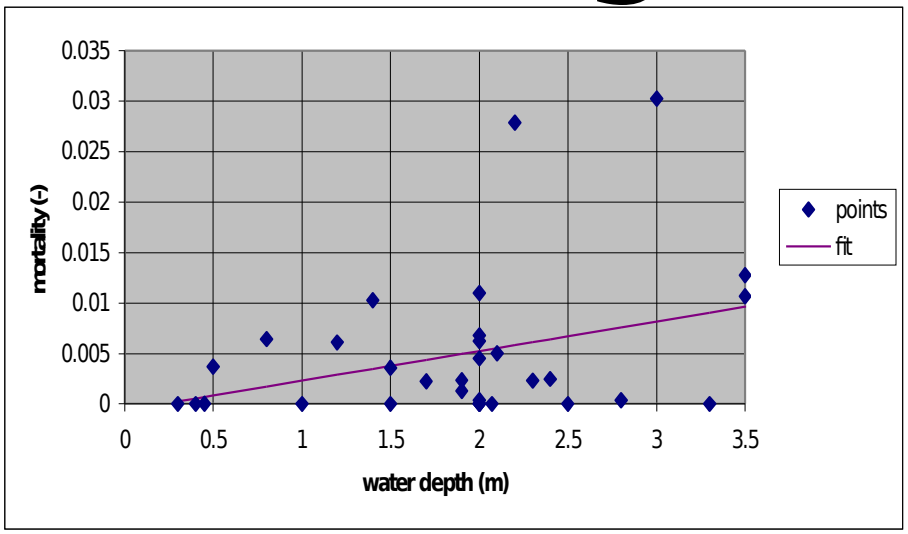

Legend
Map
Network Nodes
Network Branches
Domain ...: Model Data
Z-data (Model)
Domain ...: Model Data
Z-data (Model)
<= 0.20
> 0.20
> 0.40
> 0.60
> 0.80
> 1.00
> 1.20
> 1.40
> 1.60
> 1.80
> 2.00
> 2.20
> 2.40
> 2.60
> 2.80
> 3.00
> 3.20
> 3.40
> 3.60
> 3.80
> 4.00
> 4.20
> 4.40
> 4.60
> 4.80
> 5.00
> 5.20
> 5.40
> 5.60
> 5.80
> 6.00
> 6.20

# Casualties in flood disasters





# Models for estimating casualties



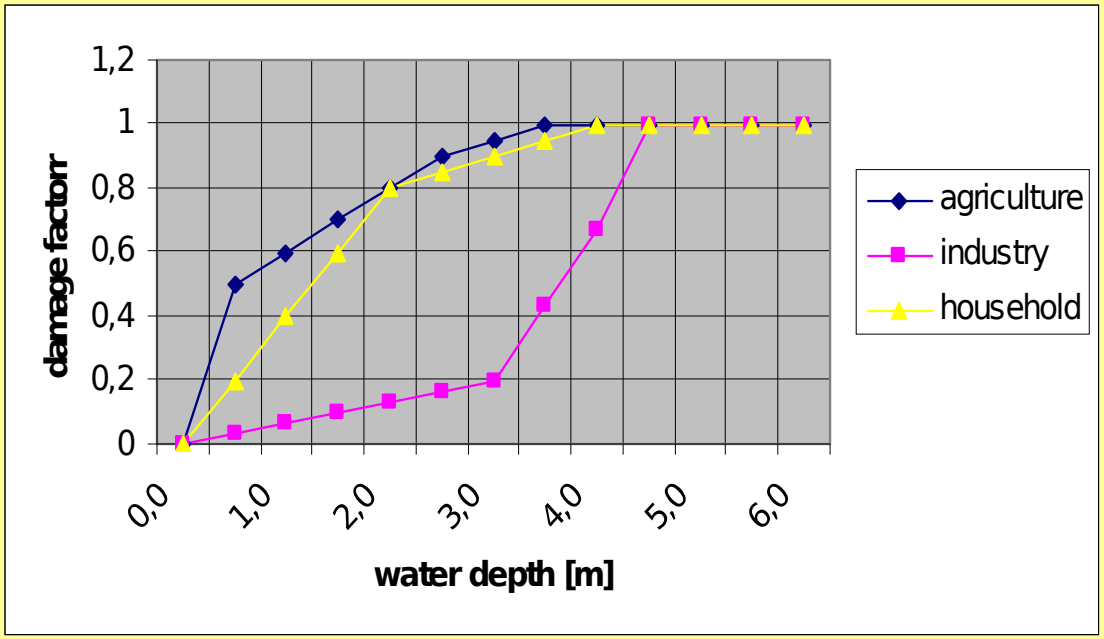
# Direct economic losses

$$C = \Sigma \alpha_k c_k n_k$$

$\alpha$ = damage factor

c = maximum damage

n = number




| | maximum damage c | |
|---|---|---|
| agriculture | 3 000 000 | Euro per $km^2$ |
| industry | 200 000 | Euro per employee |
| households | 150 000 | Euro per house |

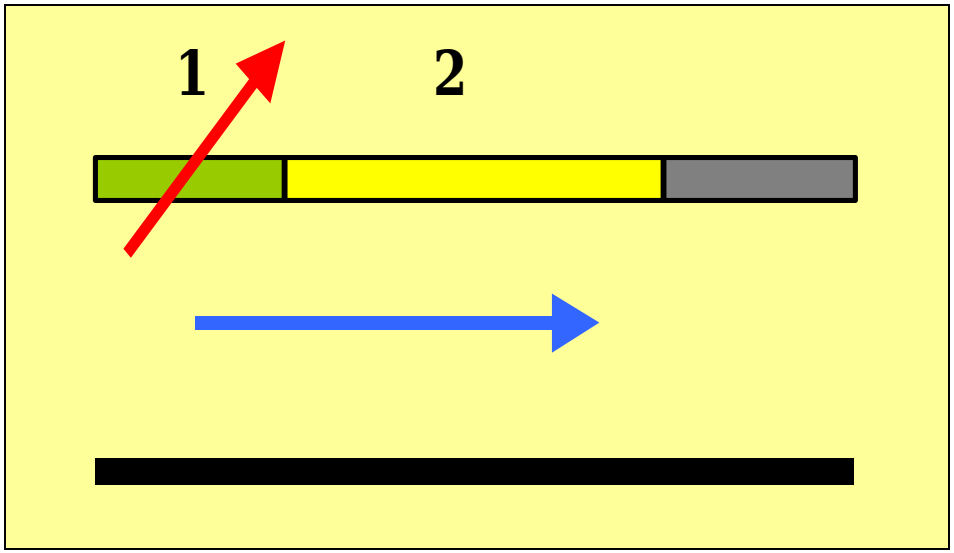
# STEP 6 Risk analysis calculation

**Standard case:**

$$\text{Risk} = P_F * C$$

**But: consequences may depend on failure mode or values of random variables**

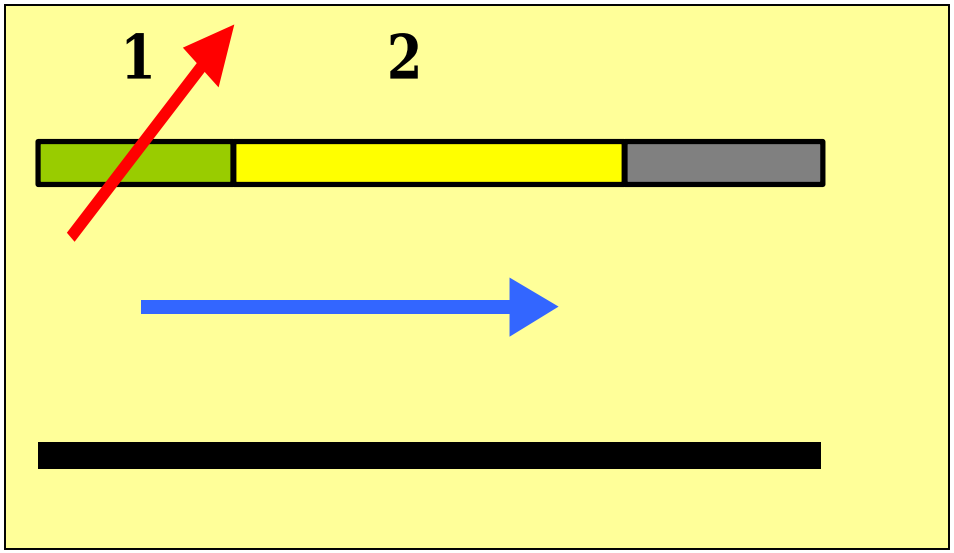
# Consequences may depend on breach location or type of mechanism




**If $C_1 \neq C_2$ then:**

**$R \neq P (Z_1<0 \cup Z_2<0) * C$**

# Scenario analysis:



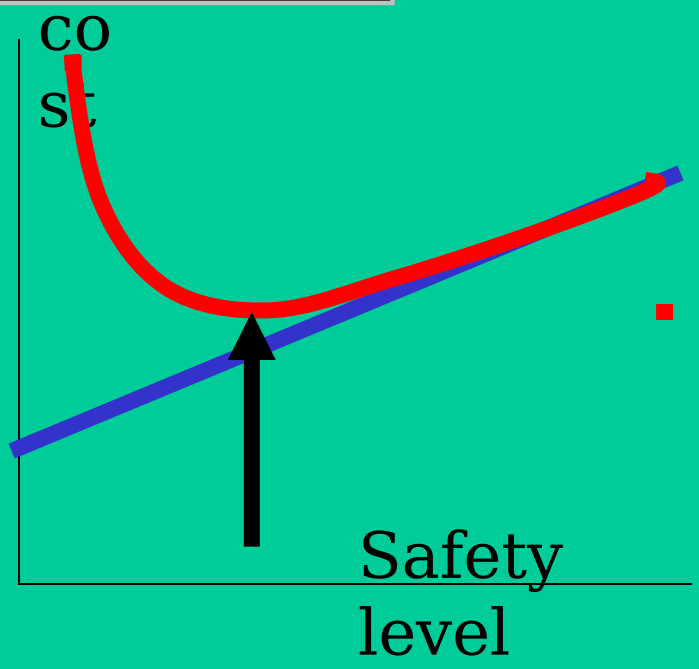

**Scenario analysis:**

- $P(Z_1<0 \cap Z_2>0)*C(Z_1<0 \cap Z_2>0)+$
- $P(Z_1>0 \cap Z_2<0)*C(Z_1>0 \cap Z_2<0)+$
- $P(Z_1<0 \cap Z_2<0)*C(Z_1<0 \cap Z_2<0)$

# Step 7 Assessment, management communication and decision

- present situation
- possible measures (study or work)
- optimisation
- human safety criteria
- risk communication

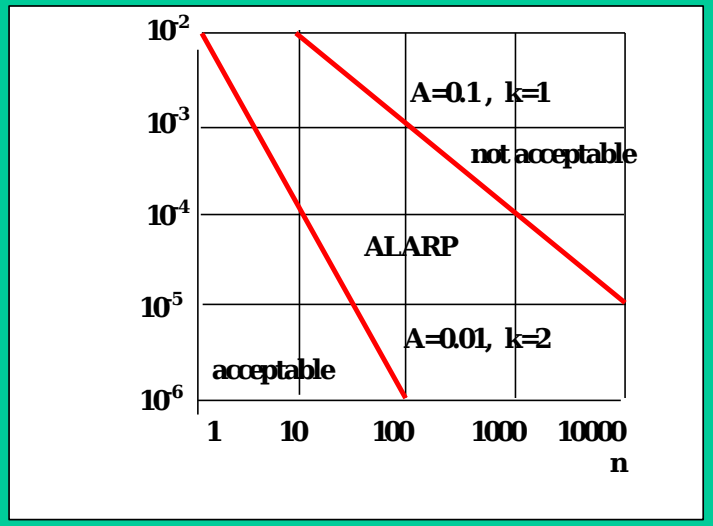
# Decision criteria




Economic optimization

P(casualty) < β $10^{-4}$ per year

Individually acceptable level of risk




Socially acceptable level of risk

# Risk Communication

**with whom ?**

**civil servants**

**politicians**

**press**

**public**

# Conclusive discussion

- **Flood protection is a perfect application field for risk and reliability analysis**
- **Calculation tools are not the bottleneck**
- **Data partly observations / partly judgement**
- **Communication and presentation is important**

# Statistical uncertainty